PATENT SPECIFICATION

(11) 1294466

DRAWINGS ATTACHED

(21) Application No. 54025/69 (22) Filed 4 Nov. 1969

(31) Convention Application No. A11305 (32) Filed 20 Nov. 1968 in

(33) Austria (OE)

(45) Complete Specification published 25 Oct. 1972

(51) International Classification B01F 5/04

(52) Index at acceptance

B1C 14 18A1 18A2 4 5 B1A B1C B2B B2E B3

1294466

(54) APPARATUS FOR INJECTING GAS INTO LIQUIDS

(71) We, VOGELBUSCH GESELLSCHAFT M.B.H., of Mautner Markhof-Gasse 40, Vienna XI, Austria, an Austrian Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to apparatus for injecting gas into fluids, and in particular to superfine aeration of nutrient media when cultivating microorganisms. The term "fluid" as used in the specification is used in its narrow sense as meaning "liquid", except where otherwise repugnant to the context.

Apparatus of this kind is known in which the fluid to be injected with the gas has the gas fed into it through porous ceramic elements, perforated hollow bodies or similar devices round or through which the fluid flows. The injection of gas by means of jet pumps is also already known.

Very fine distribution of the gas can be achieved with porous ceramic elements but the gas is subject to a relatively high throughput resistance and the elements are also very susceptible to fouling and consequent blockage of the pores. Perforated hollow bodies with relatively larger holes do not block so easily but the resultant mass transfer between the gaseous and fluid phases is found by experience to be not very good. Hollow bodies of this kind are generally expensive to manufacture since they require a good deal of material, and boring the holes involves an excessive amount of work. In addition, it is extremely difficult to make the hollow bodies such that the same pressure conditions prevail at all holes when fluid is flowing round or through the hollow body. It can even happen that instead of the gas escaping from individual apertures fluid in fact penetrates into the hollow body. Furthermore it is difficult to control eddy shedding of the flow from the surfaces which is often the cause of too high an energy consumption in keeping the fluid in motion. In addition, in known apparatus the gas injection devices are most often at a considerable depth below the liquid level, in fact near the floor of the container, as a result of which the gas has to be fed under pressure. Finally, with respect to jet pumps, for these to function satisfactorily a considerable fluid pressure is required to achieve which a great deal of energy has to be expended.

However, apparatus for superfine distribution of gases in fluids is already known whereby vacuoles or cavities are formed in the fluid to be injected with gas by means of one or more baffles at the rear of the apparatus, the gas then passing through the inside of the vacuoles or cavities to their surface where it escapes in extremely fine bubbles, particularly in the vortex train of the vacuoles or cavities. In this known apparatus the baffles forming the vacuoles or cavities are moved at a suitable velocity in the fluid to be injected with gas, for which reason they take the form of vanes extending from a rotating hollow body. The hollow body is fitted with a gas supply line and the vanes moving in the fluid are in the form of grooves open on the side away from the direction of motion and radiating outwards towards the walls of the container. Good results have been obtained with apparatus of this kind particularly in the case of superfine aeration of nutrient media in microbiological processes since the oxygen of the supplied air is relatively well used, up to about 25% when cultivating yeasts, and correspondingly large quantities of air can be introduced so that the microorganisms rapidly multiply. It is essential for vacuole or cavity formation that the baffles in the form of vanes should move through the fluid to be injected with gas at a sufficient velocity but this results in the fluid being entrained and rotated as well, as a result of which relative motion of the vanes with respect to the fluid is decreased and consequently the formation of vacuoles or cavities is disturbed. Entrainment of the fluid therefore has to be prevented to a substantial extent by suitable braking devices, in the form of plates or other elements. But these not only give rise to

a high energy consumption in moving the vanes but are also a disadvantage in that eddies are formed behind such devices in addition to other phenomena occurring which are harmful to a good gas distribution. Thus with the known apparatus efforts must be made to keep the fluid stationary which hinders its circulation and consequently hinders mixing of the separate zones of the fluid. To be able to inject gas throughout the whole fluid, the moving vanes, through which the gas is fed to the vacuoles or cavities and by these to the fluid, have to be arranged near the floor of the container, that is at a considerable depth below the fluid level so that the rising gas bubbles spend as long as possible in the fluid. Due to the relative motion of the vanes in relation to the fluid there is in fact a smaller pressure directly behind the vanes than in the adjacent layers of the fluid, but the pressure difference is in general too small to suck sufficient gas into the vacuoles or cavities by overcoming a high static fluid pressure. It is therefore generally not possible to do without an additional feed device for the gas to be fed in since otherwise to supply sufficient gas to the fluid the baffles would have to be moved at very high speed in the fluid as a result of which the energy required to drive the gas injection apparatus would be uneconomically large. In the case of baffle vanes radiating from a rotating hollow body it is also a disadvantage that at different separations from the axis of rotation of the hollow body different peripheral speeds prevail and consequently due to the different relative motion with respect to the fluid to be injected with gas also different pressure conditions. To achieve a sufficiently low pressure at the points of the vanes next to the axis, the vanes must be moved with a correspondingly higher velocity in the fluid, as a result of which there is an excessively high peripheral velocity at the points of the vanes furthest from the axis. To produce approximately uniform conditions over the whole vane length, the vane has to be correspondingly shaped, especially since a greater volume of fluid has to be injected with gas per rotation in the outer regions of the fluid container than in the inner regions.

According to one aspect of the invention there is provided apparatus for injecting gas into a body of liquid for superfine aeration of nutrient media when cultivating microorganisms comprising in combination: a container for containing a predetermined level of liquid therein; said container including means venting the container to atmosphere; a tubular member depending into said container and opening adjacent the bottom thereof; means operatively connected to said tubular member for circulating the liquid in said container through said tubular member in a direction from top to bottom of said tubular member; and gas-introducing means in said tubular member for injecting gas into the liquid circulated in said tubular member; said gas-introducing means comprising at least one fixed hollow member closed at the top and interposed in the path of the liquid circulated through said tubular member and past which said liquid descends; the or each said hollow member opening downwardly in the direction the liquid is circulated and having a lower edge portion about which a cavity in said liquid is formed; the or each said hollow member including a gas inlet portion for connection to a source of gas to be introduced into said liquid whereby gas within said hollow member is drawn into said cavity formed at the lower edge of the hollow member and carried through the tubular member to the lower portion of the container for free gravitation upwardly through the liquid in said container as a superfine aeration.

According to another aspect of the invention there is provided apparatus for injection of gas into a liquid, the apparatus comprising: a container for the liquid; a duct having an inlet from the container into the duct below a predetermined level of liquid in the container and a first duct portion leading from said inlet, said duct including an outlet into the container from the duct below said level and a second duct portion leading from said first duct portion to said outlet; a pump connected in said first duct portion for pumping liquid from the container into said inlet, through the duct and from said outlet back into said container; and a device for injecting gas into the liquid, said device comprising at least one stationary inverted hollow member which includes a pair of spaced apart side walls having spaced apart horizontal bottom edges lying in a common horizontal plane and defining a downwardly faced opening of the or each hollow member, each said edge being longer than the spacing between said edges, the or each hollow member being closed at the top and being arranged in said second duct portion downstream of the pump so that the liquid flows past the outside of the or each hollow member and at least some of the liquid flows over the outside of the or each hollow member and falls from said edges substantially vertically downwards towards said inlet, said device including a gas supply conduit connectible to a source of gas and leading to the interior of the or each hollow member, said downwardly faced opening of the or each hollow member forming an outlet for the gas from the device into the liquid, said gas outlet being limited along two sides thereof by said edges of the or each hollow member, whereby gas from said source is introduced into the liquid due to the liquid forming a cavity underneath the or each hollow member as it flows thereover.

Two preferred forms of apparatus in

accordance with the invention each have a plurality of such hollow members respectively arranged—considered in a cross-section opening in the direction of the fluid flow—in a fan or radiating array or in a side-by-side array.

Alternatively there can be one or more annular hollow members with a plurality of gas supply guides. In such arrays all gas outlets preferably lie in one plane.

To produce stable vacuoles or partially evacuated cavities it has been found to be sufficient for the fluid to be fed past the hollow members at a velocity of 4—10 m/sec. This relatively small velocity is furthermore sufficient because the nutrient media to be aerated, in the case of microbiological processes, generally contains materials which, due to their surface activity, favour release of the supplied air in very fine bubbles behind the vacuoles or cavities.

In another embodiment in which there is a circulating device running inside or outside the liquid container, the or each hollow member can be arranged in the circulating device. The liquid to be injected with gas is then circulated and after it has been injected with gas, the gas is removed in the known way, e.g. by gravity, and the liquid with few or no gas bubbles can be again fed past the or each hollow member and injected with gas. The or each hollow member may be in communication with a gas supply line through an opening in a wall of the tubular member or duct. The or each hollow member is arranged preferably above or at most only a little below the height of the liquid level established in the container. The gas is thus introduced into the liquid at a point of small static fluid pressure or even—if the gas is air—sucked in from the atmosphere due to the vacuum prevailing in the fluid, without a special compressor being required. Thereafter the resultant gas-liquid mixture can be fed in the known way to a position of higher static liquid pressure. In this way those regions in the container at which there is a higher static pressure are supplied with sufficient gas, the liquid in the container being kept in circulation by the gas bubbles rising through it.

In accordance with a preferred embodiment the hollow members are divided into a section open on the downstream side participating in injecting gas into the fluid, and an upstream portion participating in heat exchange.

Embodiments of the invention will be described by way of example with reference to the drawings showing several embodiments of the apparatus in accordance with the invention. In the drawings:—

Figure 1 depicts the first embodiment in vertical cross-section;

Figure 2 is a section along line II—II in Fig. 1;

Figure 3 is a vertical cross-section along line III—III in Fig. 1.

Figure 4 is a vertical cross-section analogous to Fig. 3, but of an embodiment in which the hollow members do not have any section participating in heat exchange;

Figure 5 shows a front vertical section through another embodiment in which the circulating means or duct is arranged in the fluid container;

Figure 6 is a plan cross-section along line VI—VI in Fig. 5;

Figure 7 depicts another embodiment of the upper part of the circulating means or duct and the hollow member or through in front vertical section;

Figure 8 is a plan cross-section along line VIII—VIII in Fig. 7;

As shown in Figs. 1—3, hollow members closed at their tops are denoted by 1 and are arranged fixed in a part 2, having a rectangular cross-section comprising part of a liquid circulating means or duct to be described in more detail in which is included a device 3 in the form of a centrifugal pump by means of which the fluid to be injected with gas is set in flow and fed to the hollow members 1. The hollow members 1 have gas inlet apertures 4, see Fig. 2, and gas outlet apertures 5 and communicating with the gas inlet apertures 4 in fixed part 2 is the gas feed line or manifold 6 surrounding the circulating means or duct. The parts 1′ of the hollow members 1 are in the form of inverted troughs, the gas outlet apertures 5 being formed by the open rear sides of the troughs, see Fig. 1. The hollow members 1 are arranged parallel to one another starting alternatively in sequence from the wall 2′ and the wall 2″ of the part 2 of the circulating device. The hollow members 1 are thus arranged in the form of two enmeshing combs. The gas inlet apertures 4 are formed by holes in the wall 2′ or 2″ respectively. The flow-off edges 7 formed by the lower ends of the hollow members 1 extend transversely to the direction A of the fluid flowing past the flow-off edges of the hollow members all being arranged in a horizontal plane.

As can be seen, the fluid flow in the region of the hollow members 1 is vertically downwards. For the sake of ease of cleaning, the hollow members 1 can be removed from the box-like part 2 of the circulating means or duct individually or in batches or groups.

The hollow members 1 are each closed off by an intermediate, transverse partition 8 above manifold 6, see Figs. 1 and 3. The hollow member parts 1′ open to the liquid flow-off side and function to inject gas into the moving liquid, and lying upstream of each part 1′, in the direction of flow of the fluid to be injected with gas is a part 1″ serving as a heat exchanger. As is known in the case of microbiological processes, for example,

when cultivating yeasts, it is necessary to remove the resultant heat from the fluid during the process. There is a feed pipe 9 for the coolant and a pipe 10 to remove it. In the parts 1'' of the hollow members 1 there are baffle plates 11 (Fig. 3) for deflecting the coolant, these plates at the same time serving to reinforce the guide elements.

The part 2 of the circulating means or duct enclosing the hollow members 1 continues as a fall pipe 13 which widens out downwards, and extends into the fluid container 12. In the wall of the fall pipe there are suction apertures 14, the cross-section of which can be made regulatable. Set in these suction apertures are inclined sections of tube 15 through which by an injector effect foam or fluid can be sucked from the fluid container 12 into the fall pipe 13. The same effect can also be achieved by suitable shaping of the wall of the fall pipe. Below the outlet end 16 of the fall pipe 13 is arranged a horizontal plate 17 which has a deflector 18 promoting the fluid flow. The fluid container 12 has a cover 19 with a gas outlet aperture 20 in it.

From the floor 21 of the fluid container 12 another part 22 of the circulating means or duct leads to the device 3 in the form of a centrifugal pump by means of which the fluid is set in flow. From the centrifugal pump a tube 23 also forming part of the circulating means or duct leads to the part 2 of the circulating means or duct enclosing the hollow members 1.

The side vertical cross-section in Figure 4, analogous to that in Figure 3, as already mentioned shows hollow members in the form of inverted troughs 24 which have no sections participating in heat exchange. Here joining onto the part 23 of the circulating means or duct there is a guide part 25 again enclosing the hollow members 24 arranged next to one another in parallel, this guide part 25 being provided with gas inlet apertures 26 through which the gas from the gas feed pipe 27 can laterally enter the hollow members 24. The upper boundaries 24' of the hollow members 24 run from the gas inlet apertures 26 obliquely downwards so that both the fluid and also the gas flowing in are only opposed by a small flow resistance. The flow-off edges of the hollow members 24 are denoted by 24''. If what is involved here is e.g. a fermentation vat open to the air, the air to be distributed can be sucked into the hollow members 24 directly from the surrounding atmosphere, air filter 28 then being arranged in the air feed pipe 27.

When the centrifugal pump 3 is in operation the fluid in the container 12 to be injected with gas is set in circulation through the parts 22, 23, 2 and 13 of the circulating means or duct and therefore flows past the hollow members 1 (Figures 1—3) or 24 (Figure 4). The fluid passes the flow-off edges 7 or 24'' with a velocity of 4—10 m/sec, this velocity being approximately the same at all flow-off points. As a result vacuoles or partially evacuated cavities are formed at the rear side adjacent edges of the hollow members or troughs, as shown by the dotted lines in Figure 1. The gas fed through the gas pipeline 6 to the hollow members is passed through the hollow members to the vacuoles, through the insides of these and thence escapes from the surfaces of the vacuoles into the fluid in fine bubbles. The vacuole formation achieved by the fixed hollow members or "stationary troughs" takes place above the fluid level in the container 12, that is at a position of small static fluid pressure, so that the gas can be supplied at atmospheric pressure since it can be sucked into the vacuoles due to the low pressure prevailing in them. Thus it is no longer necessary to introduce the gas under pressure. The resultant gas-fluid mixture is then passed downwards through the fall pipe 13 widening downwards, i.e. outwardly flared or having a lower divergent terminal end portion like a trumpet to a position of higher static fluid pressure, namely to near the base 21 of the fluid container 12. Due to the deflector 18 on the horizontal plate 17, and the trumpet like widening of the fall pipe, the fluid outlet is in the form of an annular nozzle so that the fluid flows out radially into the fluid container 12 surrounding the fall pipe. The plate 17 achieves some separation of the gas-fluid mixture as a result of which regions of the fluid low in bubbles and regions rich in bubbles are formed, the part rich in bubbles then rising through the fluid in the container whilst the part low in bubbles is sucked under the plate 17 by the centrifugal pump 3 through the part 22 of the circulating means or duct whence it passes through the part 23 of the circulating means or duct back to the hollow members 1 or 24. Separation into the two parts of the fluid can be favoured still further by rotating the plate 17 as a result of which circulation in the fluid in the fluid container is also increased. Guide elements promoting flow can also be mounted at the lower side of the plate. The gas leaving the fluid at the surface of the fluid escapes from the container 12 through the outlet aperture 20.

In the embodiment in Figures 1—3, the fluid to be injected with gas can be brought to the desired temperature by passing a coolant or heating medium through the upper sections 1'' of the hollow members 1 with the baffle plates 11. In particular, it is necessary to be able to regulate the temperature of the fluid to be injected with gas when injecting gas into a fermenting mash since, as is known, this has to be cooled continuously during the fermentation process. If the heat exchange surfaces of the hollow members 1 are not sufficient, the fall pipe 13, plate 17 and pipe-

lines 22, 23 or even the fluid container 12 can be made double-walled, a heat transferring medium being circulated between the walls.

The foam forming from the fluid injected with gas is sucked into the fall pipe 13 through the suction apertures 14 fitted with tube sections 15 by using the flow energy of the gas-fluid mixture flowing downwards in the fall pipe 13. To achieve this suction effect the fall pipe can also be divided horizontally, the upper part being slightly constricted and the lower part slightly widened so that at the point of separation the foam is sucked by an injector or venturi effect. Finally the cross-section of the suction apertures can be varied according to the quantity of foam to be sucked in. This variation of the cross-section can be achieved by known elements such as floats, electrodes, pressure detectors or the like so that regulation is automatic. By means of such suction apertures not only foam but also fluid from the upper regions of the fluid container can be sucked in and circulated again which is particularly advantageous if the fluid contains e.g. particles which for instance due to their small specific gravity have the tendency to accumulate over the surface of the fluid in the container 12.

In the embodiment shown in Figures 5 and 6, the circulating means or duct is arranged in the fluid container 30. This circulating means or duct comprises a central rise pipe 31 and a coaxial fall pipe 32 surrounding it. At its lower end near the base 33 of the fluid container 30 the rise pipe 31 extends trumpet-like into a horizontal deflector plate 34, the transition part 35 acting as a guide element promoting flow. The plate 34 reaches with its edge 36 nearly to the wall of the fluid container. The lower end of the fall pipe 32 also widens out. There is a gas outlet aperture 38 in the cover of the fluid container 30. At the upper end of the rise pipe 31 there is a device 39 in the form of a centrifugal pump by means of which the fluid to be injected with gas is set in motion. Hollow members, closed at the tops, in the form of inverted troughs for causing the gas injection are arranged in radial formation in the upper part of the fall pipe 32. The hollow members 40 project from the wall of the fall pipe 32 radially inwards reaching right up to the rise pipe 31. The gas can be fed to the hollow members 40 opening downwards by means of an annular gas supply pipe 41 surrounding the fall pipe 32, the relevant gas inlet apertures being denoted by 42. The flow-off edges of all the hollow members 40 lie in the same horizontal plane. The fall pipe 32 is divided horizontally the upper end of the lower part widening out somewhat like a trumpet so that a suction aperture 44 for the foam or fluid is again left free between the two parts of the fall pipe. The cross-section of the annular suction aperture 44 can be varied by means of a ring plate 45 adjustable for height.

To set the apparatus in operation the rise pipe 31 together with the centrifugal pump 39 is first filled with fluid, for example by evacuation with a vacuum pump not depicted, after which the pump 39 is switched on. The fluid then passes the hollow members 40 arranged in the fluid flow as a result of which vacuoles are formed at the flow-off edges 43. The gas-filled mixture then flows downwards through the fall pipe 32 and at the end of the latter is deflected outwards into the fluid container 30 where it separates into a part low in gas bubbles and a part rich in gas bubbles under the influence of gravity. The part low in bubbles is sucked by the centrifugal pump 39 through the space under the plate 34 into the rise pipe 31 again and recirculated. The gas used, for example, in a fermentation process escapes through the gas outlet aperture 38 out of the container 30.

As already stated, Figures 7 and 8 depict another embodiment of the upper part of the circulating means or duct together with a hollow member, closed at the top, in the form of an inverted trough 53. The central rise pipe 50 is again surrounded by a coaxial fall pipe 51. Arranged in the upper end of the rise pipe 50 is a device 52, here taking the form of an axial pump, by means of which the fluid can be set in flow. In the upper part of the fall pipe 51 is arranged the hollow member 53 promoting the gas injection which in this case is an annular inverted trough concentrically surrounding the rise pipe 50. Gas is fed to the hollow member 53 by the gas inlet apertures 54. The flow-off edges of the annular hollow member are denoted by the reference number 55.

The illustration of hollow member 53, forming vacuoles, (Figure 7), in addition shows particularly clearly the cross-section with which both annular and also straight hollow members without a heat exchanger section are preferably produced.

The function of this embodiment is analogous to that of the embodiment in Figures 5 and 6. The annular vacuole formed at the flow-off edges 55 is shown by the dotted lines in Figure 7.

Instead of a single annular hollow member, there can be a plurality of such hollow members. These can be arranged concentrically or staggered in the direction of flow. In addition, the hollow members, instead of being inverted troughs, can take the form of a plurality of tubes open at the flow-off end running in the direction of flow, all the tubes being connected to a common gas supply.

In all the embodiments the quantity of gas fed to the hollow members during operation can be regulated by a throttling component. In Figures 1 and 2 such a throttling com-

ponent is denoted by 56. In addition, the performance of the circulating device when in the form of a centrifugal pump (Figures 1 or 5 and 6) or an axial pump (Figures 7 and 8), by means of which the fluid to be injected with gas can be set in flow, can be regulated by varying the speed of rotation and/or the blade angle.

The hollow members with closed tops and in the form of inverted troughs as described above with reference to the drawings are relatively cheap to manufacture compared with the above-mentioned hollow bodies of the known apparatuses, and are easy to clean. In contrast to the known fixed or rotating aeration devices, approximately uniform flow and pressure conditions prevail at the gas outlet apertures. The lines of flow separation are definite and gas-filled vacuoles or cavities are formed which automatically adopt the form most advantageous for the respective flow. The gas escapes in the known way in fine bubbles from the surface of these vacuoles or cavities, particularly at the vortex train.

In comparison with the above-mentioned known rotating aeration devices, firstly it is unnecessary to have any kind of braking devices (as mentioned earlier in the specification) since the hollow members are stationary, that is do not carry out any motion due to which the relative motion of the liquid with respect to the hollow members would be detrimentally effected. Due to the stationary arrangement of the hollow members and the resultant omission of braking devices, the high thrust stresses are avoided which would otherwise occur when the (moving) hollow members passed the braking devices. Also the above-mentioned harmful eddy formation is avoided. Since the liquid to be injected with gas does not have to be kept stationary but in complete contrast is made to flow over the hollow members in such a way as to form vacuoles or cavities, complete mixing of the fluid is ensured. The fixed hollow members do not therefore have to be arranged near the floor of the container but can lie in a liquid flow for example above the level established in the container, that is at a position of small static liquid pressure. This makes an additional feed device for the gas supply superfluous since the gas alone can be sucked or aspirated into the vacuoles or cavities due to the partial vacuum formed inside the latter because no substantial static liquid pressure has to be overcome. Finally the hollow members neither have to be specially mounted nor to be mutually balanced as was of necessity the case with guide vanes emanating from a rotating hollow body in one of the known apparatuses.

Before the statement of claims, there will be given a summarised description of the apparatuses illustrated in Figures 1 to 8 in substantially the terminology of the claims, quoting reference numerals to identify various features of the illustrated apparatuses.

Each of the apparatuses illustrated in Figures 1 to 8 is an apparatus for injecting gas into a body of liquid for superfine aeration of nutrient media with little disturbance to the liquid being treated and at a low static pressure when cultivating micro-organisms comprising in combination: a container 12 or 30 for containing a predetermined level of liquid therein; said container 12, 30 including an aperture 20, 38 venting the container to atmosphere; a tubular member 13, 32 or 51 depending into said container and opening adjacent the bottom 21 or 33 thereof; means, in the form of pump 3, 39 or 52 operatively connected to said tubular member 13, 32 or 51 for circulating the liquid in said container 12 or 20 through said tubular member 13, 32 or 51 in a direction from top to bottom of said tubular member 13, 32 or 51; and gas-introducing means in said tubular member 13, 32 or 51, (above the level of liquid in the container), for injecting gas into the liquid circulated in said tubular member; said gas-introducing means comprising at least one fixed hollow member 1, 24 or 53 closed at the top and interposed in the path of the liquid circulated through said tubular member and past which said liquid descends; said hollow member 1, 24 or 53 opening downwardly as shown in the direction the liquid is circulated and having a lower edge portion 7, 43 or 55, about which a cavity in said liquid is formed; said hollow member 1, 24 or 53 including a gas inlet portion for connection to a source of gas to be introduced into said liquid whereby gas within said hollow member 1, 24 or 53 is drawn into the cavity formed at the lower edge of the hollow member and carried through the tubular member to the lower portion of the container for free gravitation upwardly through the liquid in said container as a superfine aeration.

In each above-described and illustrated apparatus, said tubular member includes a lower divergent terminal end portion whereby the circulating liquid is decreased in velocity as it leaves the tubular member.

In each above-described and illustrated apparatus, a deflector 17, 34 extends transversely beneath the open end of said tubular member 13, 32 and above the bottom 21, 33 of said container 12, 30, said deflector 17, 34 having outer edges, e.g. 36, beyond which the liquid flows when circulated through said tubular member 13, 32 for distributing the gas contained in the liquid substantially uniformly throughout said container 12, 30, said deflector edges extending substantially toward the inner surfaces of said container.

In the apparatus of Figs. 1 to 3, said hollow member 1 includes a heat exchanger portion 1'' in said tubular member 13 the heat

exchanger portion 1″ being isolated from said gas inlet portion, for conditioning the liquid as it is circulated through said tubular member. In this apparatus, there is a plurality of hollow members in the form of a plurality of inverted, trough-shaped elements 1 each terminating in a free edge extending transversely of the tubular member through which the circulated liquid descends, the free edges being disposed in a common plane, said gas inlet portion comprising a manifold 6 surrounding said trough-shaped elements 1 and communicating with the interior thereof.

Figure 1 shows valve 56 operatively connected to said gas inlet portion for regulating the amount of gas supplied to said hollow members.

Figures 1 and 5 respectively show apertures 14 and aperture 44, connecting tubular member 13, 32 to the interior of said container 12, 30 substantially adjacent the surface of the liquid contained therein and below said gas-introducing means for aspirating foam and liquid into said tubular member after the gas has been introduced into the circulating liquid.

Figure 4 shows air filter 28 operatively connected to said gas inlet portion downstream thereof for filtering the gas being introduced therein. In the arrangement shown in Figure 4, said gas inlet portion comprises a feed pipe 27 connected laterally to the hollow members and the hollow members each include an oblique portion 24 opening downwardly into said tubular member and terminating in lower coplanar edges 24″ extending transversely of the liquid flowing through said tubular member.

As described in relation to Figures 1 to 3 and Figure 4, pump 3 is rated to move the liquid past the fixed hollow members at a velocity in the range of 4 to 10 metres per second.

In the apparatus of Figures 5 and 6 and the apparatus of Figures 7 and 8, said means for circulating liquid comprises a duct 31, 50 disposed axially within said tubular member 32, 51 and having a lower end, e.g. 35, terminating below the lower open end of said tubular member, said duct 31, 50 including a radial deflector plate 34 ending transversely beenath the tubular member 32, 51 and terminating in a free edge e.g. 36 substantially adjacent the inner surface of said container 30 for causing the circulated liquid to spread substantially throughout said container.

In the apparatus of Figures 5 and 6, there is a plurality of members formed by a plurality of downwardly opening radially arranged inverted troughs 40, closed at the top, and having free lower edges 43 in coplanar relation, surrounded by and communicating with an annular chamber 41.

In the apparatus of Figures 7 and 8, said hollow member 53 comprises an annular inverted trough, closed at the top and opening downwardly, said annular inverted trough being arranged co-axially within said tubular member 51 in spaced relation from the inner surface thereof.

Again, each of the apparatuses of Figures 1 to 8 is an apparatus for injection of gas into a liquid, the apparatus comprising: a container 12, 30 for the liquid; a duct, (shown at 22, 23, 2 and 13 in Figure 1, at 31 and 32 in Figure 5 and at 50 and 51 in Figure 7), having an inlet from the container into the duct below a predetermined level of the liquid in the container and a first duct portion 22 and 23, 31, 50 leading from said inlet, said duct including an outlet e.g. 16 into the container from the duct below said level and a second duct portion 2 and 13, 32, 51 leading from said first duct portion to said outlet; a pump 3, 39, 52 connected in said first duct portion 22 and 23, 31, 50 for pumping liquid from the container into said inlet, through the duct and from said outlet back into said container; and a device for injecting gas into the liquid, said device comprising at least one stationary hollow member 1, 40, 53 which includes a pair of spaced apart side walls having spaced apart horizontal bottom edges lying in a common horizontal plane and defining a downwardly faced opening of the or each hollow member, each said edge being longer than the spacing between said edges, the or each hollow member being closed at the top and being arranged in said second duct portion downstream of the pump so that the liquid flows past the outside of the or each hollow member and at least some of the liquid flows over the outside of the or each hollow member and falls from said edges substantially vertically downwards towards said inlet, said device including a gas supply conduit connectible to a source of gas and leading to the interior of the or each hollow member, said downwardly faced opening of the or each hollow member forming an outlet for the gas from the device into the liquid, said gas outlet being limited along two sides thereof by said edges of the or each hollow member; whereby gas from said source is introduced into the liquids due to the liquid forming a cavity underneath the or each hollow member as it flows thereover.

In the apparatus of Figures 1 to 3 and that of Figure 4, said device comprises a plurality of said hollow members, said hollow members being arranged side-by-side and spaced apart from each other to leave gaps therebetween for through-flow of the liquid.

As shown in Figures 1 and 5, in each case said inlet is outwardly flared and faces downwardly towards an axially spaced, generally horizontal deflector plate 17, 34 having a centrally disposed upward projection 18, 35 which is also downwardly flared.

In the apparatus of Figures 1 to 3, an upper part of each hollow member forms a heat exchanger and is connected to means to supply a coolant to said heat exchanger.

WHAT WE CLAIM IS:—

1. Apparatus for injecting gas into a body of liquid for superfine aeration of nutrient media when cultivating microorganisms comprising in combination: a container for containing a predetermined level of liquid therein, said container including means venting the container to atmosphere; a tubular member depending into said container and opening adjacent the bottom thereof; means operatively connected to said tubular member for circulating the liquid in said container through said tubular member in a direction from top to bottom of said tubular member; and gas-introducing means in said tubular member for injecting gas into the liquid circulated in said tubular member; said gas-introducing means comprising at least one fixed hollow member closed at the top and interposed in the path of the liquid circulated through said tubular member and past which said liquid descends; the or each said hollow member opening downwardly in the direction the liquid is circulated and having a lower edge portion about which a cavity in said liquid is formed; the or each said hollow member including a gas inlet portion for connection to a source of gas to be introduced into said liquid whereby gas within said hollow member is drawn into said cavity formed at the lower edge of the hollow member and carried through the tubular member to the lower portion of the container for free gravitation upwardly through the liquid in said container as a superfine aeration.

2. Apparatus as claimed in claim 1, in which said tubular member includes a lower divergent terminal end portion whereby the circulating liquid is decreased in velocity as it leaves the tubular member.

3. Apparatus as claimed in claim 1 or 2, in which a deflector extends transversely beneath the open end of said tubular member and above the bottom of said container, said deflector having outer edges beyond which the liquid flows when circulated through said tubular member for distributing the gas contained in the liquid substantially uniformly throughout said container, said deflector edges extending substantially toward the inner surfaces of said container.

4. Apparatus as claimed in claim 1, 2 or 3, in which the or each hollow member includes a heat exchanger portion isolated from said gas inlet portion for conditioning the liquid as it is circulated through said tubular member.

5. Apparatus as claimed in any preceding claim, in which there is a plurality of hollow members in the form of a plurality of inverted, trough-shaped elements each terminating in a free edge extending transversely of the tubular member through which the circulated liquid descends, the free edges being disposed in a common plane, said gas inlet portion comprising a manifold surrounding said trough-shaped elements and communicating with the interior thereof.

6. Apparatus as claimed in any preceding claim, and including means operatively connected to said gas inlet portion for regulating the amount of gas supplied to the or each said hollow member.

7. Apparatus as claimed in any preceding claim, and including means connecting said tubular member to the interior of said container substantially adjacent the surface of the liquid contained therein and below said gas-introducing means for aspirating foam and liquid into said tubular member after the gas has been introduced into the circulating liquid.

8. Apparatus as claimed in claim 1, 2 or 3, in which filter means is operatively connected to said gas inlet portion downstream thereof for filtering the gas being introduced therein.

9. Apparatus as claimed in claim 1, 2 or 3, in which said gas inlet portion comprises a feed pipe connected laterally to the or each hollow member and the or each hollow member includes an oblique portion opening downwardly into said tubular member and terminating in lower coplanar edges extending transversely of the liquid flowing through said tubular member.

10. Apparatus as claimed in any preceding claim, in which said means for circulating said liquid comprises a pump rated to move the liquid past the or each fixed hollow member at a velocity in the range of 4 to 10 metres per second.

11. Apparatus as claimed in claim 1, 2 or 3, in which said means for circulating liquid comprises a duct disposed axially within said tubular member and having a lower end terminating below the lower open end of said tubular member, said duct including a radial deflector plate ending transversely beneath the tubular member and terminating in a free edge substantially adjacent the inner surface of said container for causing the circulated liquid to spread substantially throughout said container.

12. Apparatus as claimed in any one of claims 1 to 3 and 11, in which there is a plurality of said hollow members formed by a plurality of downwardly opening radially arranged inverted troughs, closed at the top, and having free lower edges in coplanar relation, surrounded by and communicating with an annular chamber.

13. Apparatus as claimed in any one of claims 1 to 3 and 11, in which said hollow member comprises an annular inverted trough, closed at the top and opening downwardly, said annular inverted trough being arranged

co-axially within said tubular member in spaced relation from the inner surface thereof.

14. Apparatus for injection of gas into a liquid, the apparatus comprising: a container for the liquid; a duct having an inlet from the container into the duct below a predetermined level of liquid in the container and a first duct portion leading from said inlet, said duct including an outlet into the container from the duct below said level and a second duct portion leading from said first duct portion to said outlet; a pump connected in said first duct portion for pumping liquid from the container into said inlet, through the duct and from said outlet back into said container; and a device for injecting gas into the liquid, said device comprising at least one stationary hollow member which includes a pair of spaced apart side walls having spaced apart horizontal bottom edges lying in a common horizontal plane and defining a downwardly faced opening of the or each hollow member, each said edge being longer than the spacing between said edges, the or each hollow member being closed at the top and being arranged in said second duct portion downstream of the pump so that the liquid flows past the outside of the or each hollow member and at least some of the liquid flows over the outside of the or each hollow member and falls from said edges substantially vertically downwards towards said inlet, said device including a gas supply conduit connectible to a source of gas and leading to the interior of the or each hollow member, said downwardly faced opening of the or each hollow member forming an outlet for the gas from the device into the liquid, said gas outlet being limited along two sides thereof by said edges of the or each hollow member; whereby gas from said source is introduced into the liquid due to the liquid forming a cavity underneath the or each hollow member as it flows thereover.

15. Apparatus as claimed in claim 14, wherein said device comprises a plurality of said hollow members, said hollow members being arranged side-by-side and spaced apart from each other to leave gaps therebetween for through-flow of the liquid.

16. Apparatus as claimed in claim 14 or 15, wherein said inlet is outwardly flared and faces downwardly towards an axially spaced, generally horizontal deflector plate having a centrally disposed upward projection which is also downwardly flared.

17. Apparatus as claimed in claim 14, 15 or 16, wherein an upper part of the or each hollow member forms a heat exchanger and is connected to means to supply a coolant to said heat exchanger.

18. Apparatus as claimed in claim 1 and substantially as herein described with reference to and as illustrated in Figures 1 to 3 of the accompanying drawings.

19. Apparatus as claimed in claim 1 and substantially as herein described with reference to and as illustrated in Figures 1 to 3 modified according to Figure 4.

20. Apparatus as claimed in claim 1 and substantially as herein described with reference to and as illustrated in Figures 5 and 6 of the accompanying drawings.

21. Apparatus as claimed in claim 1 and substantially as herein described with reference to and as illustrated in Figures 7 and 8 of the accompanying drawings.

MARKS & CLERK,
Chartered Patent Agents,
Agents for the Applicant(s).

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1972
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1294466 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

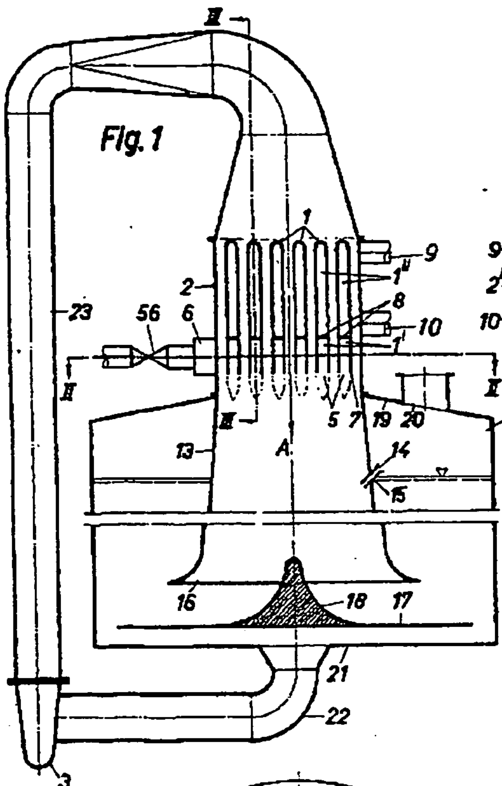


Fig. 1

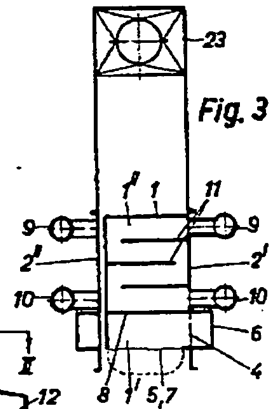


Fig. 3

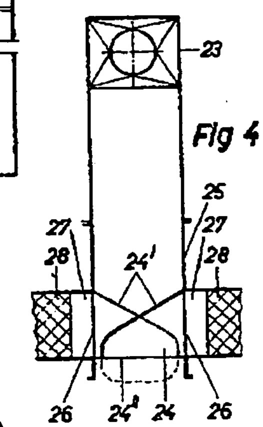


Fig 4

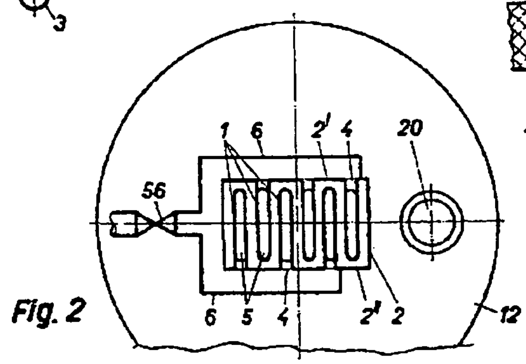


Fig. 2

1294466 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

Fig. 5

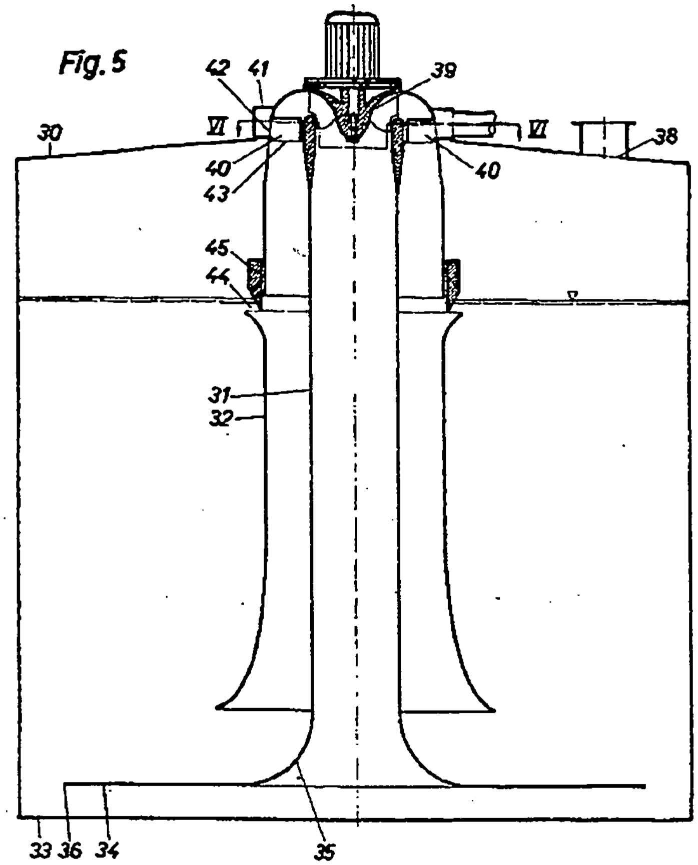


Fig. 6

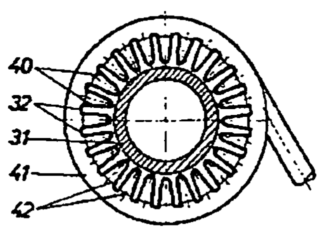
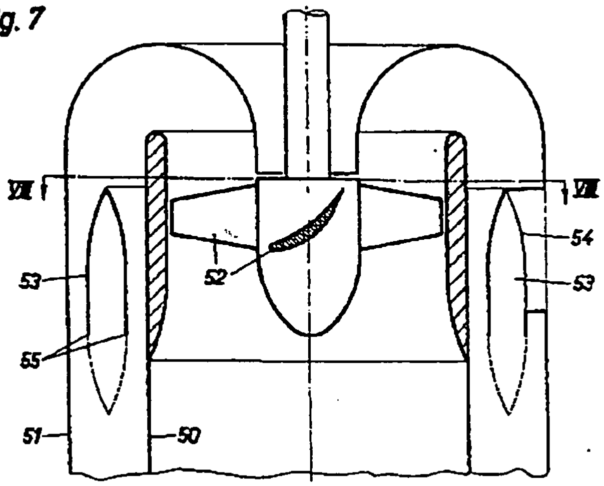


Fig. 7



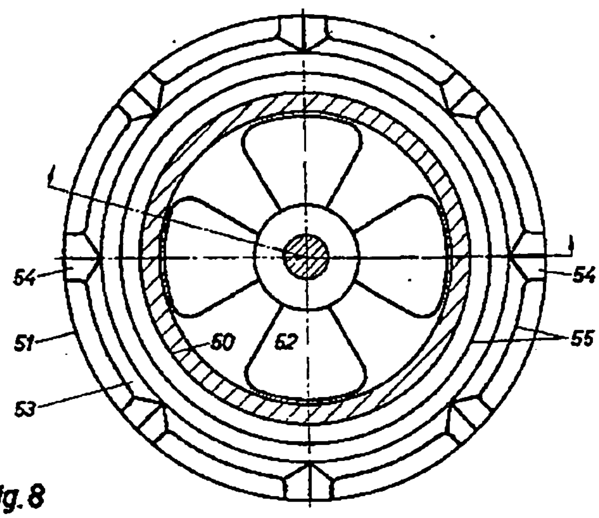


Fig. 8